A. General Information of the Soil Tracts of Uttar Pradesh

Soils of the state have been broadly classified into six important groups (Mehrotra, 1966). These comprise of (1) Hill soils, (2) Bhabar or the submountain soils, (3) Tarai soils, (4) Bundelkhand soils, (5) Vindhyan soils, and (6) soils of the Gangetic alluvium. In addition to these a very small fragment of the state also occupies the soils of Arawali hills which is an extension of the similar soils in Rajasthan. Their distribution is shown in the attached map of Uttar Pradesh. A detailed account of these soils have been reported by Ray Chaudhary et al (1968).

These soil groups have been derived from both residual as well as alluvial origin. The residual soils include the soils of Hill, Bundelkhand and Vindhan regions while that of alluvial region comprise of Gangetic alluvial as well as Tarai soils. Bhabar soils are the submountain soils, lying at the base of Siwaliks, are developed from the physical translocation of finer materials from the adjoining mountains on the rocky substratum in the form of their colluvial deposits. Hill soils have been developed from granites, gneiss, biotite-schists and phyllites under subtemperate climate with Oak, pine and undergrowing weeds of forest vegetation. The soil associations recognized in this group include (1) the red loam, (2) brown forest soils, (3) podsols, and (4) Wiesenbodens.
The hill bottom or the submountain soils comprise of thin deposits of fine texture soils underlain by pebbles and coarse gravels. Due to their rocky substratum the soils are excessively permeable and do not hold water for long even though the area receives the entire effluent water of Himalaya's. The numerous riverlutes and streams reaching this area disappear underground and emerge again in the adjoining alluvial tract of Tarai.

Tarai soils comprise of the coarser materials transported from the Siwalik ranges which due to the strong water velocity escape deposition in Bhabhar region and are laid in the form of thick deposits in Tarai region. They are underlain at considerable depths by the rocky outcrops which are found in undulating conditions at depths ranging from 8-40 ft. It is on this account that sub-aquial reservoirs and artisan wells are often met within this area. The important soil associations of the area include (1) Tarai sandy loam, (2) Tarai loam, Calcareous and noncalcareous, (3) Clay loam, calcareous and noncalcareous and (4) Tarai clays.

The residual soils of Bundelkhand and Vindhyan regions have originated from the Vindhyan table lands which passes through the centre of the country and skirts the state into South Western and South Eastern parts in areas adjacent to Madhya Pradesh. Bundelkhand soils have also developed from granites, quartzites and other numerous sedimentary rocks giving rise to four
broad soils associations including the soils of (1) rocky ridges, (2) brownish and grey loams soils, (3) coarse grained black soils, and (4) clayey black soils. The first two soils are gravelly to sandy loam in texture and are shallow. The latter two soils are fine textured and deep; that last one being extremely deep and comprise of black clays. The light textured soil chiefly grow coarse grains including bajra.

The Vindhayan soils in the south east are developed mostly on Kaimure and Vindhayan sand stones and are very shallow invariably underlain by undecomposed parent rock. Eleven important series have been recognized although the main associations are (1) Vindhayan uplands, (2) Vindhayan flats and (3) Vindhayan lowlands (limited to a small area).

Soils of the Gangetic plains developed on Gangetic alluviums are unfathomably deep and have been mainly laid out by the river systems of Ganga, Yamuna and their tributaries. The parent material of these alluviums are the softer rocks principally of calcareous origin such as dolmites, calcifars etc. mechanically transported from the system of rocks through which these rivers traverse in their upper extremeties in Himalayas. The alluviums have been deposited in the form of sediments of varying particle sizes and nature. Those laid in the upper extremeties are sandy and in the lower extremeties silty or clayey in
nature. The particle size have also been governed by the velocity of the flow. The faster streams laid coarse textured soils and in the slower ones fine textured soils were deposited. Genetically these soils have been divided into four main broad groups (1) recent alluvium, (2) the flats, (3) upland and (4) lowlands. The recent alluviums are invariably calcareous, sandy to silty loam in texture whose soil profile exhibit signs of complete immaturity even though the sedimented layers, deposited at different times, are distinctly visible. These are found nearest to the river banks and are invariably underlain by a bed of river sand. Such soils are better suited to cucurbits and other inferior crops.

The soils of the flats are deeper soils found at slightly higher elevations and are considered very productive. The soil profile exhibits sign of maturity and the horizon differentiations are distinctly marked. The surface soils are loam in texture while the soils of illuviated horizons are clay loam resulting from translocations and depositions of finer particles from upper layers. The illuviation of bases from the surface to lower depths are also distinctly displayed principally in the form of sesquioxide and lime concretions. The parent horizons in these soils are sandy loam to sandy in texture and often of non-calcareous nature. These soils have been developed under water logged conditions and profiles exhibit
signs of mottling. These soils are particularly suitable for paddy, pea and sugarcane.

The upland soils are found at the highest elevations and their profile exhibit all the zonal characters and are fully mature soils. These are sandy to sandy loam at the surface with an illuviated clay loam horizon at lower depths and are underlain by the sandy parent material. They are brown to reddish brown in colour, devoid of bases, plant nutrients, non-calcareous and slightly acidic in reaction. They are excessively drained and have a very low water table. The soils due to the severe depletion in the nutrient status are extremely responsive to fertilizer treatments and are used for all types of cereals or cash crops, such as, wheat, maize, smaller grains, legumes, sugarcane and potato.

The soils of lowlands are found within the depressionary pockets in the upland areas and have been developed principally from the washings of the finer material of the upland areas during years of heavy rainfall or floods. These are clayey in nature, very stiff when dry and sticky when wet. The soil profiles show zonal characters in association with features of water logging in the form of ferrigenous mottlings. The soils are particularly suitable for paddy cultivation.

Alluvium of different systems differ from one another only in the nature of parent material which give
rise to soils of varying compositions but genetically with similar features of profile development. Marked variations are visible within a river system resulting from the variations in the location of area. The soils in the upper extremities in north or north west corners of the state are lighter in texture with coarser soil particles while in the south these are finer and more enriched with bases which have formed part of the soil as a result of the washings from the upper courses. The soil profiles in the west are developed under semi-arid conditions while those in the south east are developed under humid to sub-humid conditions. Bajra crop is grown principally in areas of recent alluviums and uplands on sandy to sandy loam soils largely in the trans Yamuna area in the districts of Agra and Mathura, and the sandy soil areas of mid east in the districts of Allahabad and Kanpur. In residual region it is grown both in Bundelkhand and Vindhayan regions. The soils selected for the studies were therefore taken from Agra, Allahabad, Kanpur and Jhansi districts. The specific nature of the four soils are indicated in the following lines.

Table 1. Morphological and Physico-chemical characteristics of the soils selected for the study

<table>
<thead>
<tr>
<th>Name of the location</th>
<th>Kanpur (Pura Farm, Madhavpur)</th>
<th>Allahabad (Itmadpur)</th>
<th>Agra (Bharari Farm)</th>
<th>Jhansi (Bharari Farm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological 0-25 cm.</td>
<td>0-20 cm. 5 Y 6/4 pale 2.5 Y 7/4 pale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>2.5 Y, 7/2 light grey, 5 Y 6/4 pale 2.5 Y 7/4 pale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>olive (2.5Y yellow (10 YR 5/2 greyish 5/4 yellowish (10 YR 5/4 7/1 dry, brown wet) brown wet) yellowish 4/1 moist, loamy sand, sandy loam,</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
brown when loamy sand 
loamy, friable, light structureless, non-calcareous, non-alkaline in reaction. 
loamy, friable, light structureless, non-calcareous, non-alkaline in reaction. 
loamy, friable, light structureless, non-calcareous, non-alkaline in reaction. 
loamy, friable, light structureless, non-calcareous, non-alkaline in reaction. 
loamy, friable, light structureless, non-calcareous, non-alkaline in reaction. 
3
4
5
granular
slightly acidic
alkaline
slightly acidic
alkaline
slightly acidic
alkaline

Analysis
Sand %
Silt %
Clay %
pH
Total Nitrogen %
Organic carbon %
CaO %
P2O5 %
K2O %
Total Exchangeable m.e %
Ex-Ca m.e %

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.60</td>
<td>71.10</td>
<td>72.99</td>
<td>68.88</td>
<td></td>
</tr>
<tr>
<td>22.23</td>
<td>16.65</td>
<td>14.87</td>
<td>14.83</td>
<td></td>
</tr>
<tr>
<td>16.04</td>
<td>10.00</td>
<td>9.53</td>
<td>15.72</td>
<td></td>
</tr>
<tr>
<td>7.2</td>
<td>6.8</td>
<td>6.5</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>0.056</td>
<td>0.042</td>
<td>0.026</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>0.438</td>
<td>0.338</td>
<td>0.143</td>
<td>0.284</td>
<td></td>
</tr>
<tr>
<td>0.46</td>
<td>0.45</td>
<td>0.28</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>0.096</td>
<td>0.140</td>
<td>0.066</td>
<td>0.140</td>
<td></td>
</tr>
<tr>
<td>0.610</td>
<td>0.710</td>
<td>0.522</td>
<td>0.750</td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td>9.0</td>
<td>9.6</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>7.6</td>
<td>6.8</td>
<td>6.6</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

The soil analyses done after the harvest of the bajra crop did not show any change in the individual constituents except nitrogen, where too, the differences were negligible.

B. Preparation of the Soils for Pot Experiment

Fields were cleared of the vegetation above the ground level. Soil samples were drawn up to a depth of 20 cm in one sq. meter area from about 25 spots of the field. These were thoroughly mixed, put into gunny bags and transported to the experimental site.
Individual soils were passed through sieve and 20 kg air dry soil was filled in each cement pot. Aldrin was thoroughly mixed in the soil to prevent damage from termites. Weighed quantities of sulphate of ammonia, superphosphate and sulphate of potash were added as a basal manure to supply 40, 20, 20 kg/ha of N, P and K respectively just a day before sowing. The pots were placed in a randomized design in the pot area. Similarly in field experiments land was well prepared and Aldrin was mixed along with basal manuring a day before sowing.

C. Treatment of Hybrid Bajra Seed, Sowing and After Care

Seeds of hybrid bajra variety HB1 were put into a salt solution. Healthy seeds were washed and treated with Captan and two seeds were sown in each pot. After germination the two plants were thinned to one in each pot. In field experiments sowings were done behind desi plough which were thinned to keep a distance of 45 cms. from plant to plant. Weeding and hoeings were done whenever needed. The pots were shifted to wire netting house as soon as the cobs started appearing to prevent damage from birds. All prescribed plant protection measures were adopted to maintain the crop in a healthy condition.
D. Plant Sampling Methods

The growth and the developmental traits recorded were on the basis of four plants from each treatment. Plant samples were taken starting from a fortnight after planting till harvesting at the growth stages of seedling, tillering, flag leaf, heading and harvesting. The whole plant was wiped off the moisture with a filter paper, chopped into fine pieces and put into separate paper bags bearing the respective labels of the treatments. After allowing them to dry in the sun they were transferred to forced air oven to dry at 70°C for 24 hours. Having been dried the weight was taken immediately for evaluation of dry matter and the samples were ground in a Wiley mill. On completion of thorough mixing of the ground samples, a sub-sample was drawn and placed in air tight bottles for subsequent chemical analyses.

E. Details of the Observations Recorded

(i) Height of the plant: Prior to flowering, height was measured from the base of the top most fully unfurled leaf to the lowest node of the plant. After flowering, the upper limit fixed was the base of panicle.

(ii) Tiller and Leaf numbers per plant: The total number was counted from four plants and averaged out on per plant basis.
(iii) **Panicle morphology** : was studied on the basis of four plants taken out at random at milk and harvest stages. The panicle components were the length of panicle, number of panicles and 1000 grain weight.

(iv) **Grain and fodder yield** : The panicles from the harvest rows from the plots were collected and counted. The plants without panicles were cut nearest to the ground for sun drying till they attained nearly the constant weight which was recorded as fodder yield. Panicles were threshed and grain was separated from chaff, cleaned and weighed.

**F. Soil Sampling and Soil Analysis**

For soil analysis surface samples were collected after harvesting of crop up to a depth of 15 cm. from each pot, with the help of a small core sampler, dried in the shade and passed through 2 mm sieve. These were stored in bottles for determining their important constituents.

(i) **pH determination** : pH determination was done on a Beckman Model H2 pH meter using glass electrode.

(ii) **Total Nitrogen** : was determined by modified Kjeldahl’s method as given in A.O.A.C. (1955).

(iii) **Organic Carbon** : was performed by rapid titration method of Walkley and Black (Piper 1947).

(iv) **Phosphates** : was estimated by Ammonium molybdate method (A.O.A.C. 1955).
(v) Potassium: Volumetric Cobaltinitrite method as followed by (Piper 1947).

(vi) Calcium Oxide: was estimated as oxalate precipitate in HCl extract (A.O.A.C. 1955).

(vii) Total Exchangeable Bases: was determined by Ammonium Acetate method (A.O.A.C. 1955).


(ix) Technical analysis: By modified Robinson Pipette method (Wright 1939).

G. Plant Analysis: The oven dried material taken from the dry matter estimation was redried and subjected to chemical analyses.

(i) Nitrogen: was estimated by modified microkjeldalh's method (A.O.A.C. 1955).

(ii) Phosphorus: was determined by digesting the plant material as described by Snell and Shell and estimated colorimetrically using a Spekker Absorption meter.

(iii) Potassium: Plant material was digested as given in (A.O.A.C. 1955) and estimations were made by cobaltinitrite volumetric method as given in (Piper 1947).

H. Quality Analysis

(1) Density of grain: The known weight of the grain from each treatment was taken. The grain was submerged
in water contained in graduated cylinder. The rise in water level gave the volume of grain. From this, density was obtained dividing the weight by volume.

(ii) **Protein content of grain** : The crude protein content was obtained by analysing the total nitrogen content of grain according to A.O.A.C. (1955) procedures and multiplying the percentage figures obtained with a factor of 6.25.

(iii) **Carbohydrates** : determined by Hanson Walker (1906) as modified by Bertrand and described in Locasie and Shull (1937).

(iv) **Fat** : The grains after grinding were extracted with light petroleum (b.p.40-60 C.) in Soxhlet’s apparatus.

(v) **Crude fibre** : was estimated by extracting material with ether as described in A.O.A.C. 1955.

(vi) **Calcium as Cac** : 5 gms. seed burnt in a platinum dish in a muffle at 500 to 600°C and extracted with 10% HCl. It was precipitated and estimated as described under soil analysis.

(vii) **Phosphorus** : Aliquot from the above extract was taken and precipitated as described under soil analysis.

I. **Calculations**

**Uptake of Nutrients** : Total nitrogen, phosphates and potash contents were determined in plant samples collected
during various growth stages. By multiplying the dry 
matter with the N, P and K percent of various treatments 
the uptake of these nutrients was worked out during 
various phases of growth.

(ii) Recovery : The recovery of nutrients has been 
worked out according to Donner formula : \[ \frac{X-Y}{Z} \times 100 \]

Where

\[ X = \text{lb of nutrient absorbed from the fertilized plots.} \]
\[ Y = \text{lb of nutrient absorbed from the unfertilized plots.} \]
\[ Z = \text{lb of nutrient added through the fertilizer.} \]

(iii) Rate of Uptake : Seasonal and daily rate of 
nutrient uptake at the different phases of crop growth were 
also computed on the basis of the final uptake at harvest 
and duration of the crop.

(iv) Rentability : Increase in dry matter production 
per unit of the nutrient absorbed.

(v) Partial efficiency : Partial efficiency of nitrogen 
absorbed at various growth stages was calculated according 
to the procedure described by Tanaka et al. (1959) as

\[ \frac{X_n - X_{n-1}}{Y_n - Y_{n-1}} \]

Where

\[ X_n \text{ and } Y_n \text{ are grain yield and total nitrogen} \]
\[ \text{absorbed respectively at } n-\text{th treatment stage and } X_{n-1} \text{ and} \]
\[ Y_{n-1} \text{ are same characters respectively at the } (n-1)\text{th stage.} \]

(vi) Fertilizer Efficiency : Increase in extra produce 
obtained over unfertilized control per unit of fertilizer 
applied.

(vii) Economic or Net return : The monetary gain obtained 
due to extra yield by investing every rupee on fertilizer.